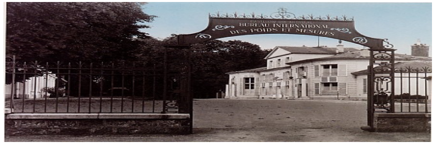
The NMI WORK
SURFACE INTERCOMPARISON

Paola Iacomussi



OUTLINE

- Intercomparison
- Review of SURFACE Intercomparison tasks
- Participant
- Reference Materials / Certified Reference Materials
- Data Analysis
  - Reference value
  - DOE
- What we learned

Intercomparison

- BIPM website on the KCDB database has no results about road surface intercomparison.
- One was about luminance coefficient evaluation

We need intercomparison to test

- How much the measurements are comparable
- Traceability chain
- Better understand device performances
- To compare each others
- To test uncertainty statements

Intercomparison and uncertainty

Uncertainty: is a measure of the quality of measurement results

No measurement is exact, even if the quantity were measured several time providing the same value is not a proof of the exact value but means only that the measuring system has not a sufficient resolution to distinguish between the different values of the quantity

Measurement uncertainty is not a concept equivalent to *error*: all measurements results are affected by errors. Sources of errors can be identified then quantified and corrected, depending on time and resources available

Intercomparison and uncertainty

The definition of *measurement uncertainty* is a requirement stated in several documents (European standard incl)

Intercomparison is a way to check *uncertainty* reliability

VIM JCGM 200

GUM JCGM 100

https://www.bipm.org/en/publications/guides/

Definitions, concepts, metrological terms*

Set of operations having the object of determining a value of a quantity.

Magnitude of a particular quantity expressed as a unit of measurement multiplied by a number.
EXAMPLE: r value of road **824** sr^{-1}

3.1.1 The objective of a **measurement** is to determine the **value** of the **measurand**, that is, the value of the particular to be measured.
A measurement therefore begins with an appropriate specification of the measurand, the **method of measurement** and the **measurement procedure**.

Particular quantity subject to measurement.
EXAMPLE: **Luminance coefficient (q)** of road surface

Logical sequence of operations, described generically, used in the performance of measurements.

Set of operations, described specifically, used in the performance of particular measurements according to a given method.

* From the *International vocabulary of basic and general terms in metrology* (VIM)

B.2.11

result of a measurement

value attributed to a measurand, obtained by measurement

It is an estimate of the value of the measurand.

NOTE 2 A complete statement of the result of a measurement includes information about the uncertainty of measurement.

B.2.18

uncertainty (of measurement)

parameter, associated with the result of a measurement, that characterizes the dispersion of the values that could reasonably be attributed to the measurand.

It indicates the degree of reliability in the result.

B.2.14

accuracy of measurement

closeness of the agreement between the result of a measurement and a true value of the measurand

…

NOTE 2 The term **precision** should not be used for "accuracy".

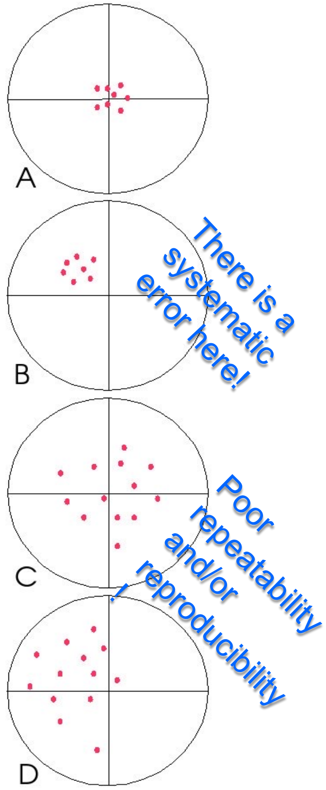
2.15 [JCGM 200:2012, International vocabulary of metrology – Basic and general concepts and associated terms (VIM)]

measurement precision

closeness of agreement between **indications** or **measured quantity values** obtained by replicate **measurements** on the same or similar objects under specified conditions

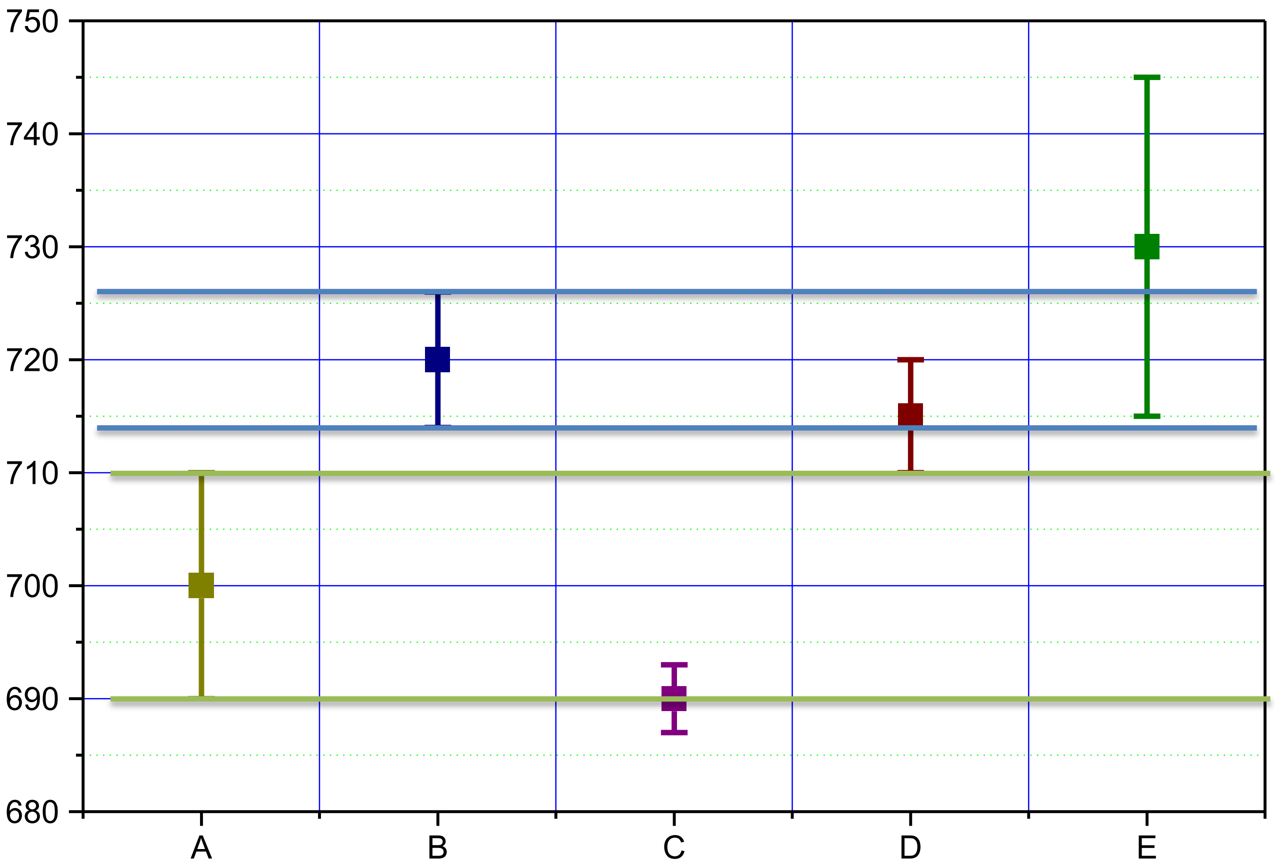
…

NOTE 2 The 'specified conditions' can be, for example, **repeatability conditions of measurement**, **…** or **reproducibility conditions of measurement …**



SURFACE Intercomparison tasks

- To check metrological capability
  - Measurement methods
  - Uncertainty evaluation
- RM suitability
- Check expected uncertainty



750
740
730
720
710
700
690
680
A
B
C
D
E

Uncertainty evaluation

Measurement uncertainty could be described as composed by two contributions:

- the measurement system metrological characteristics and measurement procedures,
- the influence of the measured specimen characteristics

JCGM guide is a powerful document but its application is considered very difficult for every day work, especially if considering industrial photometric measurements

Measurement methods

- Absolute

$$q_{\mathrm{T}} = \frac{s_{\mathrm{L,T}} - s_{\mathrm{L0,T}}}{s_{\mathrm{E,T}} - s_{\mathrm{E0,T}}} \cdot \frac{k_{\mathrm{L}}}{k_{\mathrm{E}}}$$

- Relative

$$q_{\mathrm{T}} = q_{\mathrm{R}} \frac{s_{\mathrm{L,T}}}{s_{\mathrm{L,R}}} \cdot \frac{s_{\mathrm{M,R}}}{s_{\mathrm{M,T}}}$$

SURFACE Intercomparison tasks

4. QUANTITIES TO MEASURE

- **<u>Reduced luminance coefficient</u>**
- **<u>Q0 and S1 values</u>**

Before performing the measurements please read carefully these instructions and the questionnaire to be filled, enclosed in the pack.

At least three measurements of each artefact and for each measuring geometry must be carried out, which means taking out the reference material before the next measurement.

The **<u>reduced luminance coefficient</u>** and **<u>Q0 and S1 values</u>** of the artefacts must be measured following the measuring procedure of each laboratory for the given observation angle.

Measured values: r table

ANNEX B - STANDARD REFLECTION TABLES

Table C1

	β(°)																			
tgγ	0	2	5	10	15	20	25	30	35	40	45	60	75	90	105	120	135	150	165	180
0	770	770	770	770	770	770	770	770	770	770	770	770	770	770	770	770	770	770	770	770
0,25	710	708	703	710	712	710	708	708	707	704	702	708	698	702	704	714	708	724	719	723
0,5	586	582	587	581	581	576	570	567	564	556	548	541	531	544	546	562	566	587	581	589
0,75	468	467	465	455	457	446	430	420	410	399	390	383	373	384	391	412	419	437	438	445
1	378	372	373	363	347	331	314	299	285	273	263	260	250	265	278	295	305	318	323	329
1,25	308	304	305	285	270	244	218	203	193	185	179	173	173	183	194	207	224	237	238	245
1,5	258	254	251	229	203	178	157	143	134	128	124	120	120	132	140	155	163	177	179	184
1,75	217	214	205	182	153	129	110	100	95	90	87	84	88	98	103	116	123	134	137	138
2	188	181	174	142	116	95	80	73	69	64	62	64	64	72	78	88	95	105	108	109
2,5	145	136	121	90	66	53	46	41	39	37	36	36	39	44	50	55	60	66	69	71
3	118	108	87	57	41	32	28	26	25	23	22	23	25	28	31	37	41	45	47	51
3,5	97	87	64	39	26	20	18	17	16	15	15	16	17	19	23	27	30	33	35	37
4	80	69	50	29	17	14	13	12	11	11	11	11	13	15	17	19	22	26	27	29
4,5	70	58	37	21	13	10	9	8	8	8	8	9	10	12	14	16	17	20	21	22
5	60	51	29	15	9	7	7	6	6	6	6	7	7	9	10	12	14	17	17	18
5,5	52	41	23	12	7	6	6	6	5	4										
6	48	36	19	8	6	5	5	5	5											
6,5	44	32	17	7	6	5	5	5												
7	41	28	14	6	5	4	4	4												
7,5	37	26	12	6	4	3	3													
8	34	23	11	5	4	3	3													
8,5	32	21	9	5	4	3	3													
9	29	19	8	4	3	3														
9,5	27	17	7	4	3	3														
10	26	16	6	3	3	3														
10,5	25	16	6	3	2	1														
11	23	15	6	3	2	1														
11,5	22	14	6	3	2															
12	21	14	5	3	2															

Table C1 Qd/Q0 = 0,090/0,100 *S*1=0,24

SURFACE Intercomparison tasks

4. QUANTITIES TO MEASURE

- **Reduced luminance coefficient**
- **Q0 and S1 values**

Before performing the measurements please read carefully these instructions and the questionnaire to be filled, enclosed in the pack.

At least three measurements of each artefact and for each measuring geometry must be carried out, which means taking out the reference material before the next measurement.

The **reduced luminance coefficient** and **Q0 and S1 values** of the artefacts must be measured following the measuring procedure of each laboratory for the given observation angle.

Table 2: Directions in which the measured values will be compared

<table>
<tr><th colspan="5">Lighting Angles</th><th>Observation angle</th></tr>
<tr><th>tan ε</th><th>ε / °</th><th colspan="2">β/ °</th><th>Additional β/ °</th><th>α/°</th></tr>
<tr><td></td><td></td><td rowspan="8">0</td><td rowspan="8">15</td><td rowspan="8">30</td><td rowspan="8">1</td></tr>
<tr><td>0</td><td>0</td></tr>
<tr><td>1</td><td>45</td></tr>
<tr><td>2</td><td>63.43</td></tr>
<tr><td>4</td><td>76</td></tr>
<tr><td>6</td><td>80.5</td></tr>
<tr><td>8</td><td>82.9</td></tr>
<tr><td>11.5</td><td>85</td></tr>
</table>

Table 3: Additional observation angles

Additional Observation angles α
2.29°
10°
20°

Measured values: r table

CIE 144:2001

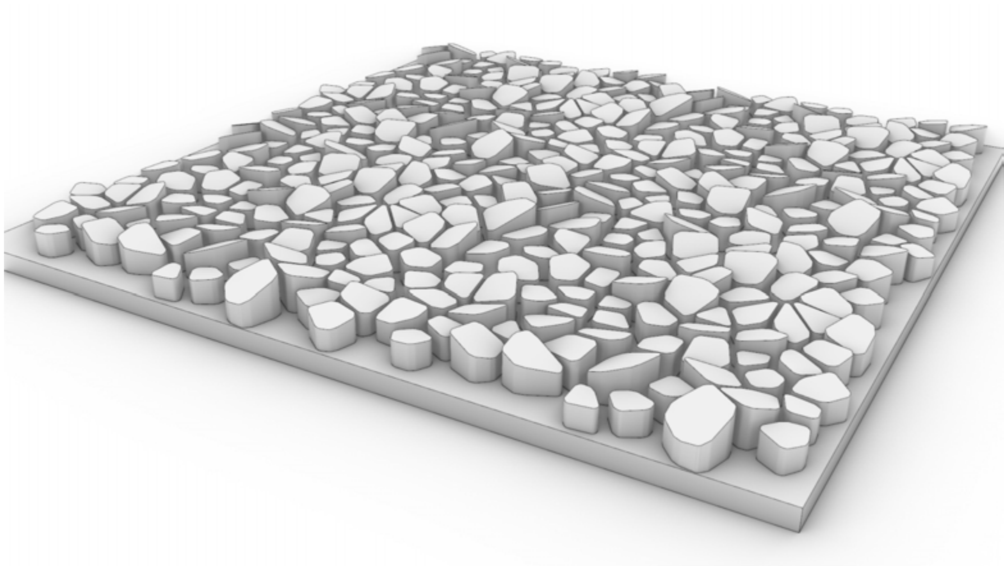
ANNEX B - STANDARD REFLECTION TABLES

Table C1

$tg\gamma$	β(°) 0	2	5	10	15	20	25	30	35	40	45	60	75	90	105	120	135	150	165	180
0	770	770	770	770	770	770	770	770	770	770	770	770	770	770	770	770	770	770	770	770
0,25	710	708	703	710	712	710	708	708	707	704	702	708	698	702	704	714	708	724	719	723
0,5	586	582	587	581	581	576	570	567	564	556	548	541	531	544	546	562	566	587	581	589
0,75	468	467	465	455	457	446	430	420	410	399	390	383	373	384	391	412	419	437	438	445
1	378	372	373	363	347	331	314	299	285	273	263	260	250	265	278	295	305	318	323	329
1,25	308	304	305	285	270	244	218	203	193	185	179	173	173	183	194	207	224	237	238	245
1,5	258	254	251	229	203	178	157	143	134	128	124	120	120	132	140	155	163	177	179	184
1,75	217	214	205	182	153	129	110	100	95	90	87	84	88	98	103	116	123	134	137	138
2	188	181	174	142	116	95	80	73	69	64	62	64	64	72	78	88	95	105	108	109
2,5	145	136	121	90	66	53	46	41	39	37	36	36	39	44	50	55	60	66	69	71
3	118	108	87	57	41	32	28	26	25	23	22	23	25	28	31	37	41	45	47	51
3,5	97	87	64	39	26	20	18	17	16	15	15	16	17	19	23	27	30	33	35	37
4	80	69	50	29	17	14	13	12	11	11	11	11	13	15	17	19	22	26	27	29
4,5	70	58	37	21	13	10	9	8	8	8	8	9	10	12	14	16	17	20	21	22
5	60	51	29	15	9	7	7	6	6	6	6	7	7	9	10	12	14	17	17	18
5,5	52	41	23	12	7	6	6	6	5	4										
6	48	36	19	8	6	5	5	5	5											
6,5	44	32	17	7	6	5	5	5												
7	41	28	14	6	5	4	4	4												
7,5	37	26	12	6	4	3	3													
8	34	23	11	5	4	3	3													
8,5	32	21	9	5	4	3	3													
9	29	19	8	4	3	3														
9,5	27	17	7	4	3	3														
10	26	16	6	3	3	3														
10,5	25	16	6	3	2	1														
11	23	15	6	3	2	1														
11,5	22	14	6	3	2															
12	21	14	5	3	2															

Table C1 Qd/Q0 = 0,090/0,100 *S*1=0,24

Measurand



SURFACE Intercomparison tasks


16NRM02
01-DG-000
16NRM02
01-DK-000
4


16NRM02
01-DG-210
16NRM02
01-DK-210
0


2
16NRM02
01-GK-210
16NRM02
01-DG-110


6
16NRM02
01-GK-000

VALUES

4. QUANTITIES TO MEASURE

- **Reduced luminance coefficient**
- **Q0 and S1 values**

Before performing the measurements please read carefully these instructions and the questionnaire to be filled, enclosed in the pack.

At least three measurements of each artefact and for each measuring geometry must be carried out, which means taking out the reference material before the next measurement.

The **reduced luminance coefficient** and **Q0 and S1 values** of the artefacts must be measured following the measuring procedure of each laboratory for the given observation angle.

Participants

3 consortium members
2 stakeholders
4 laboratory goniometers
4 portable devices

- L872 (1)
- R345 (1)
- A109 (1)
- H118 (1; 2,29)
- E155 (1; 2,29; 10)
- M762 (1; 2,29; 10; 20)
- F563 (1; 2,29; 10; 20)
- C123 (1; 2,29; 10; 20)

Discrepancies approach

Approach 1

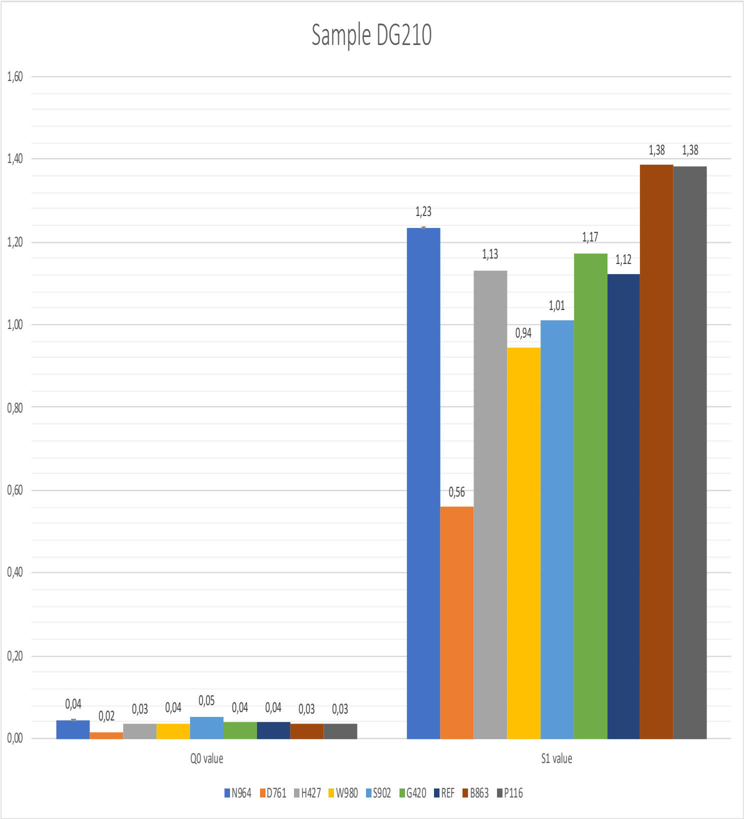
- Definition of a KCRV
  - Artimetic mean
- Definition of uncertainty
  - Of KCRV
  - Of ILC participants
  - By own procedure
  - By LUMCORUN

Approach 2

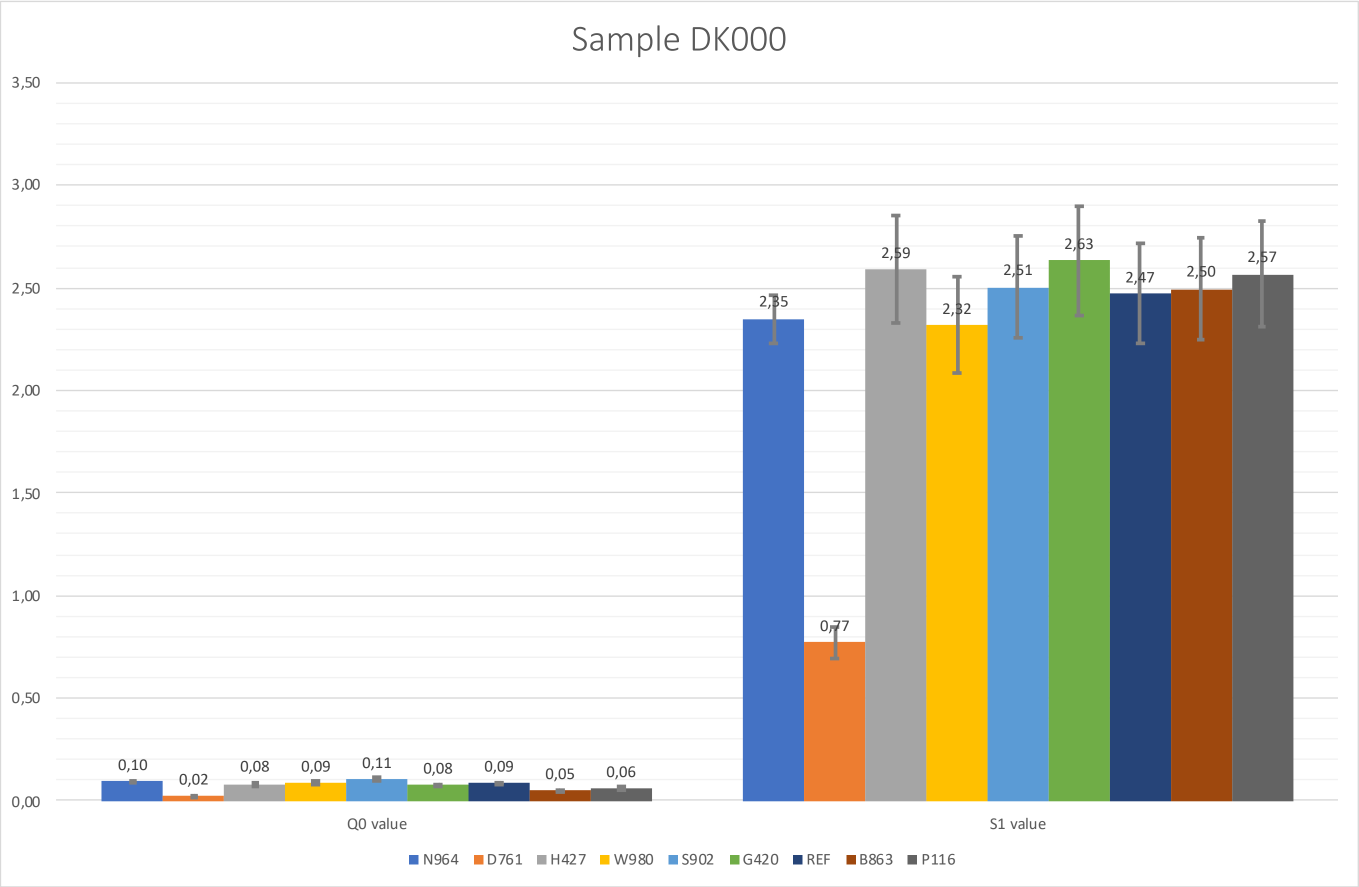
- Check all values
- Use the expected uncertainty
- Outliers

Approach 2: 1° observation Integral Values

- Expected relative uncertainty 2%- 10%

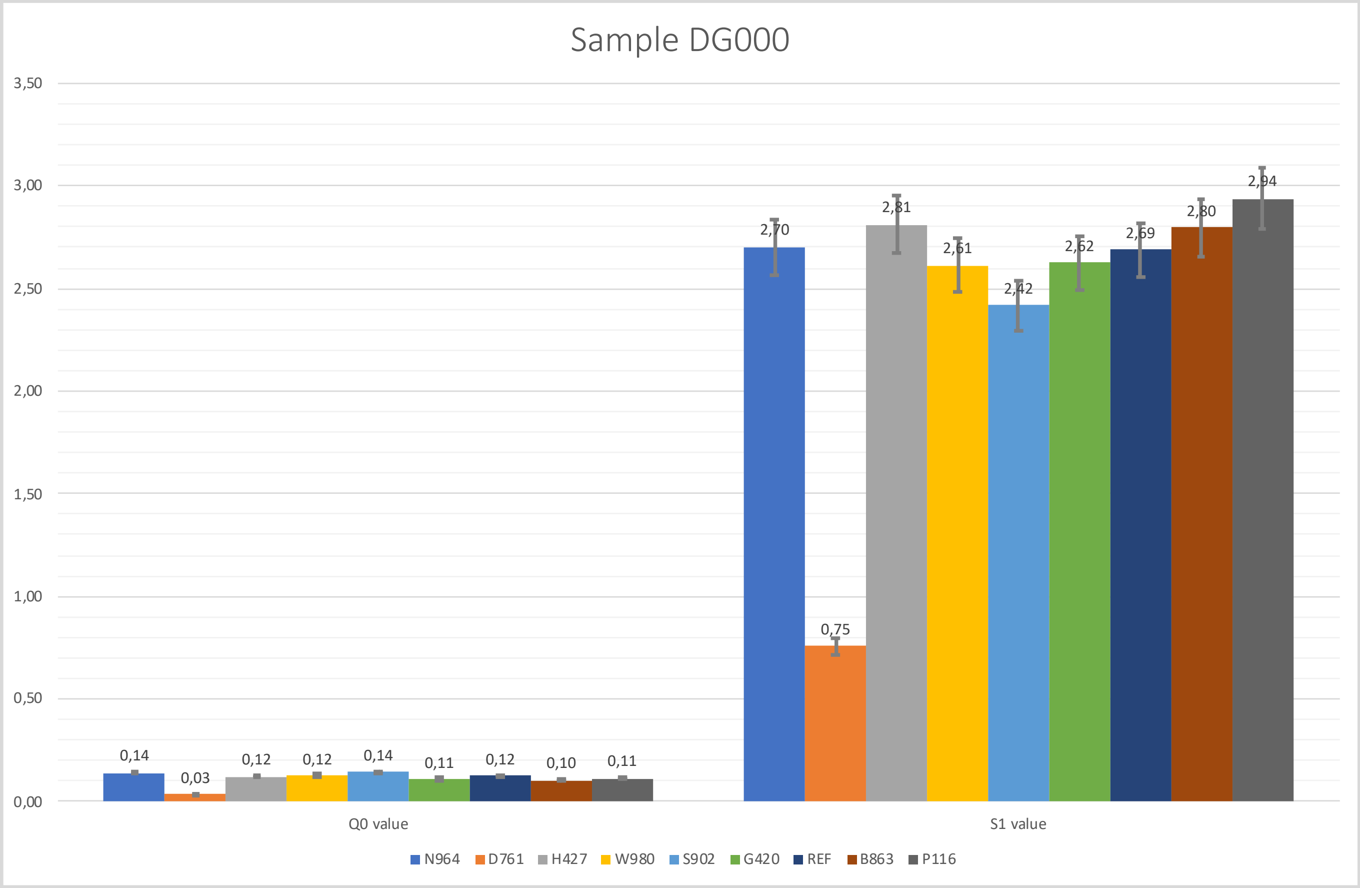


DIFFUSE BLACK FLAT DK000



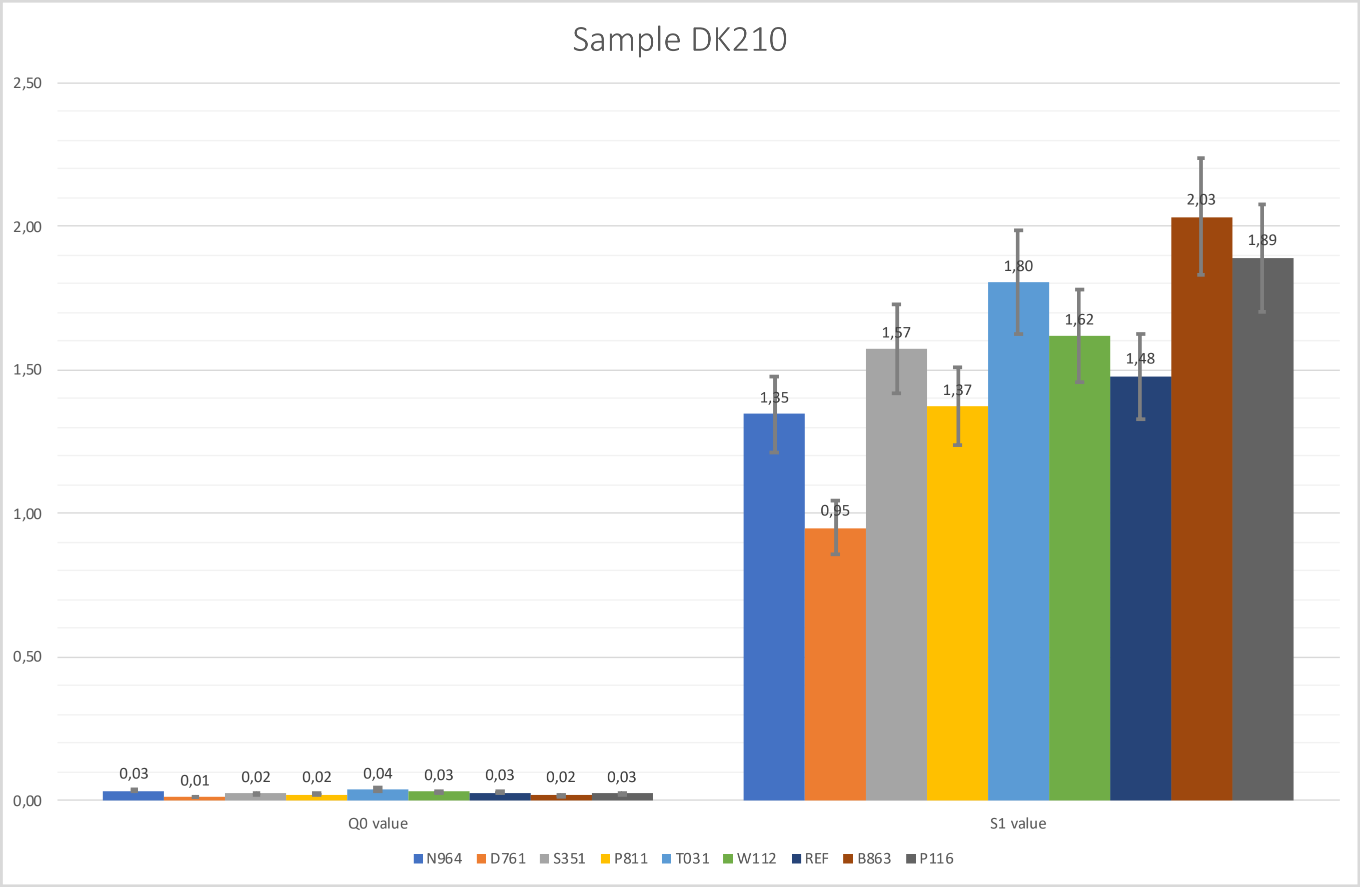
10%

DIFFUSE GREY FLAT DG 000



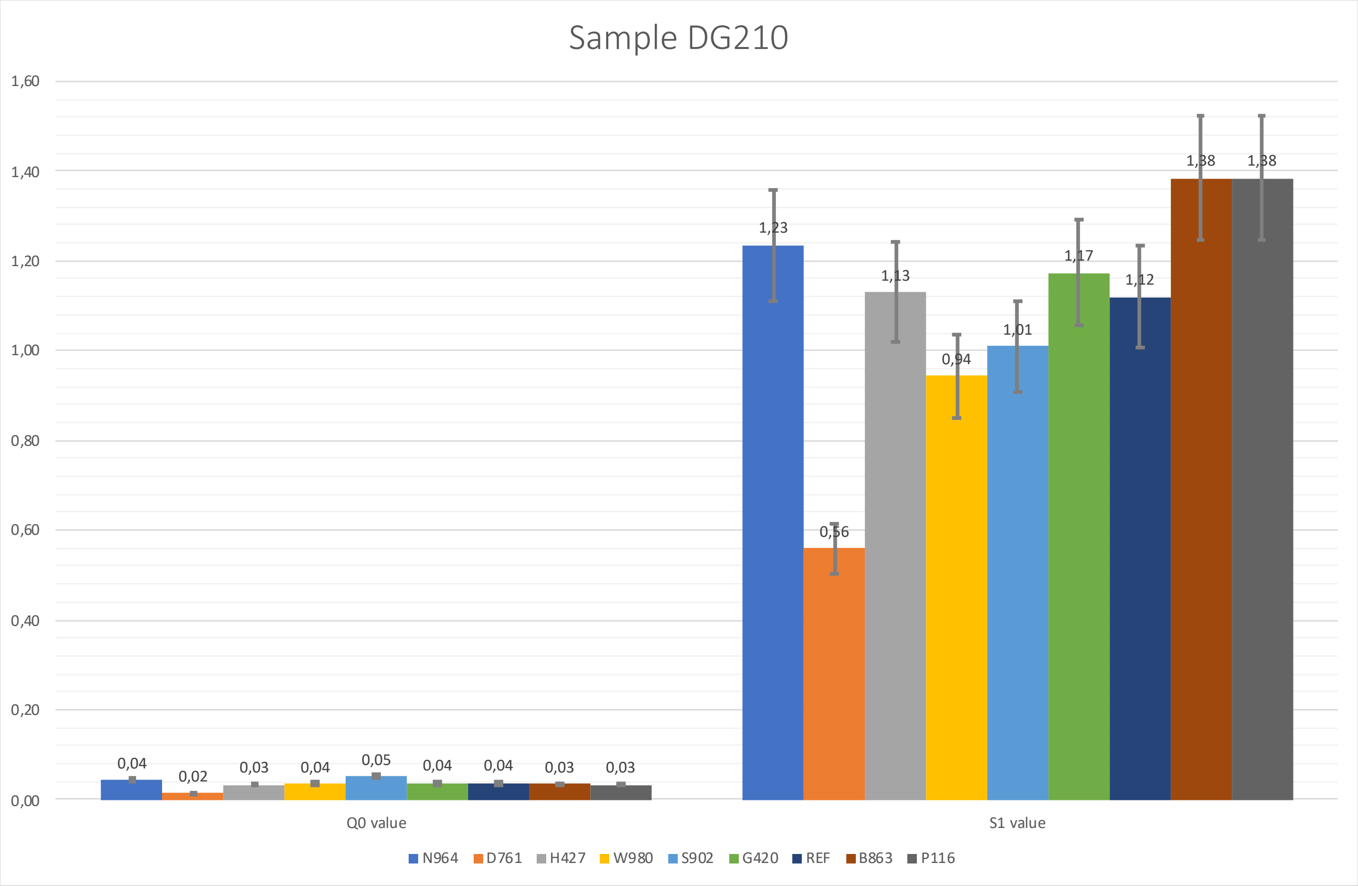
5%

DIFFUSE BLACK LOW HEIGHT DK210



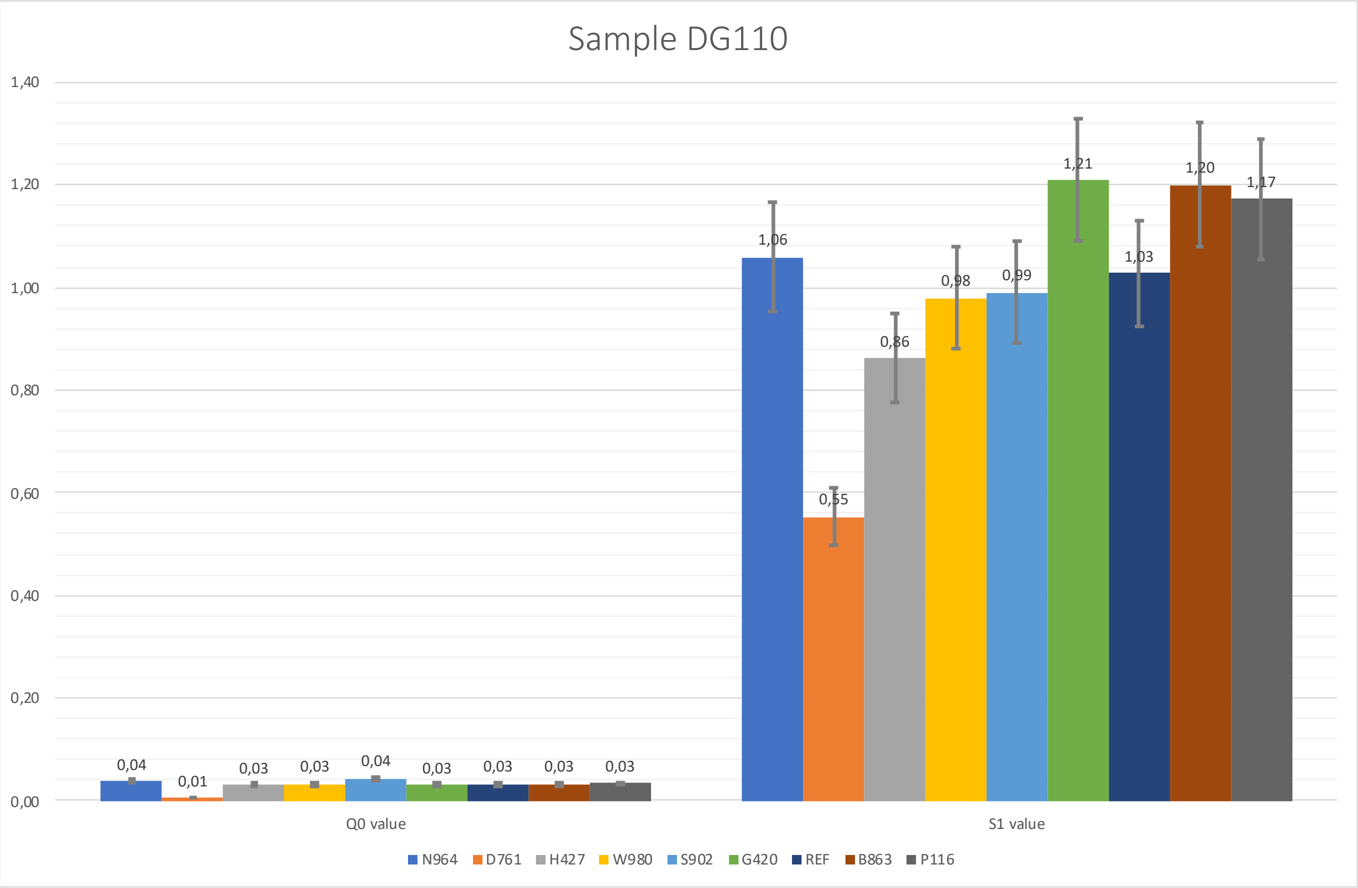
10%

DIFFUSE GREY LOW HEIGHT DG210



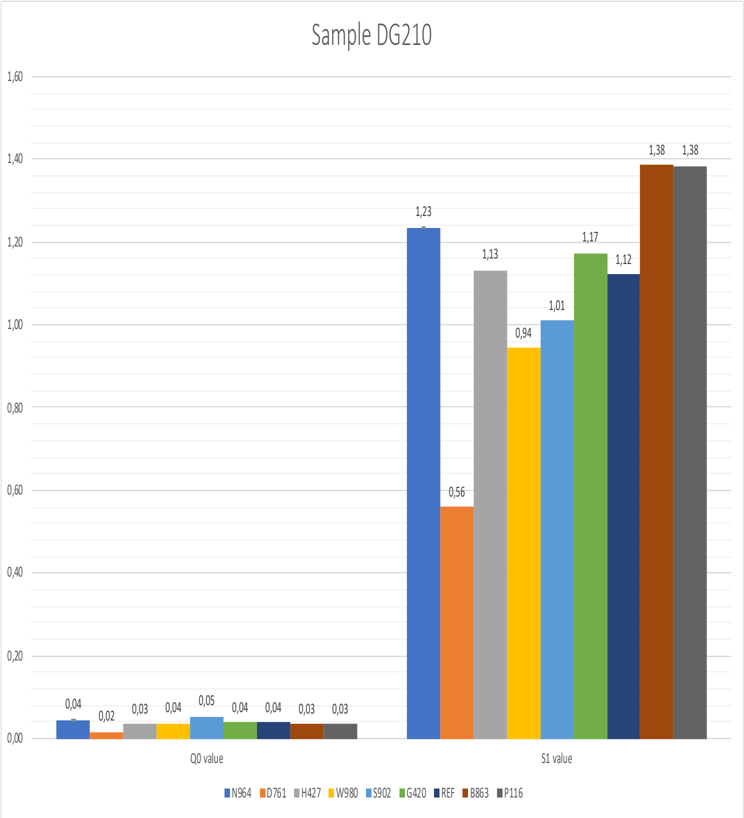
10%

DIFFUSE GREY HIGH HEIGHT DG110



Approach 2: 1° observation r values

- Expected relative uncertainty 2%- 10%

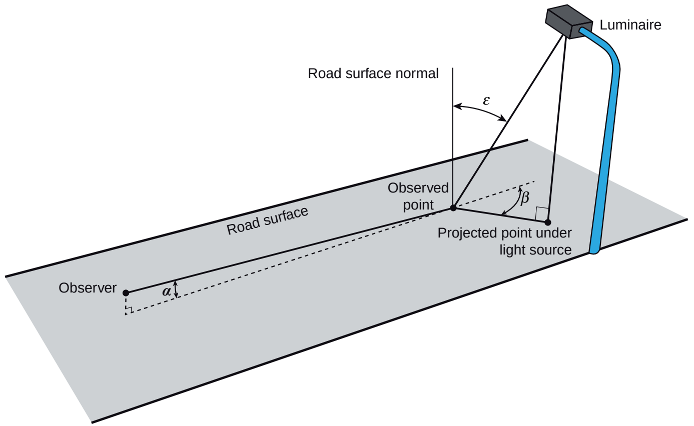


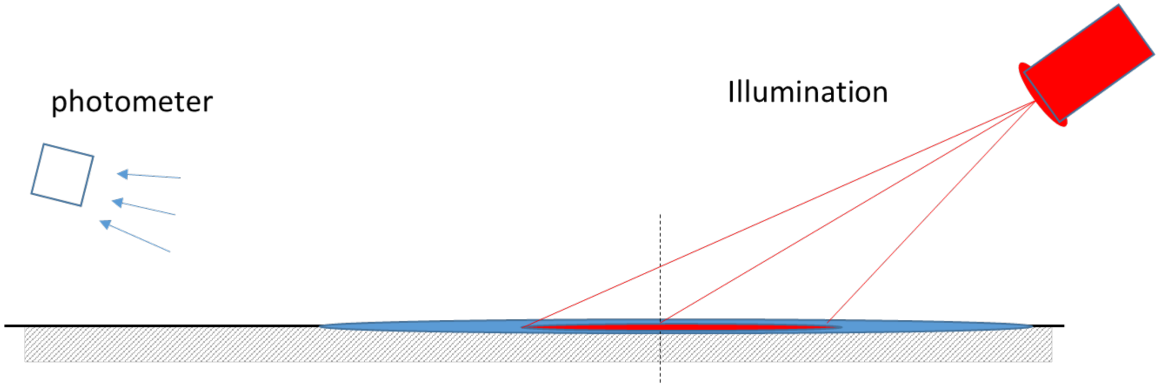
DG110

DK210

DG210

Instrument aperture effect





Instrument aperture effect

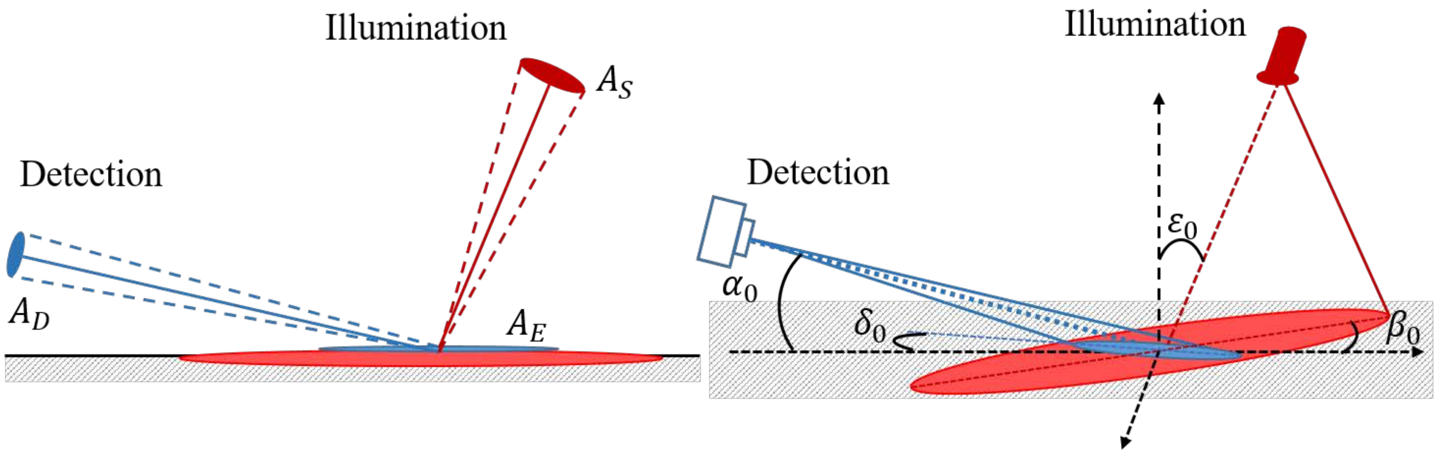
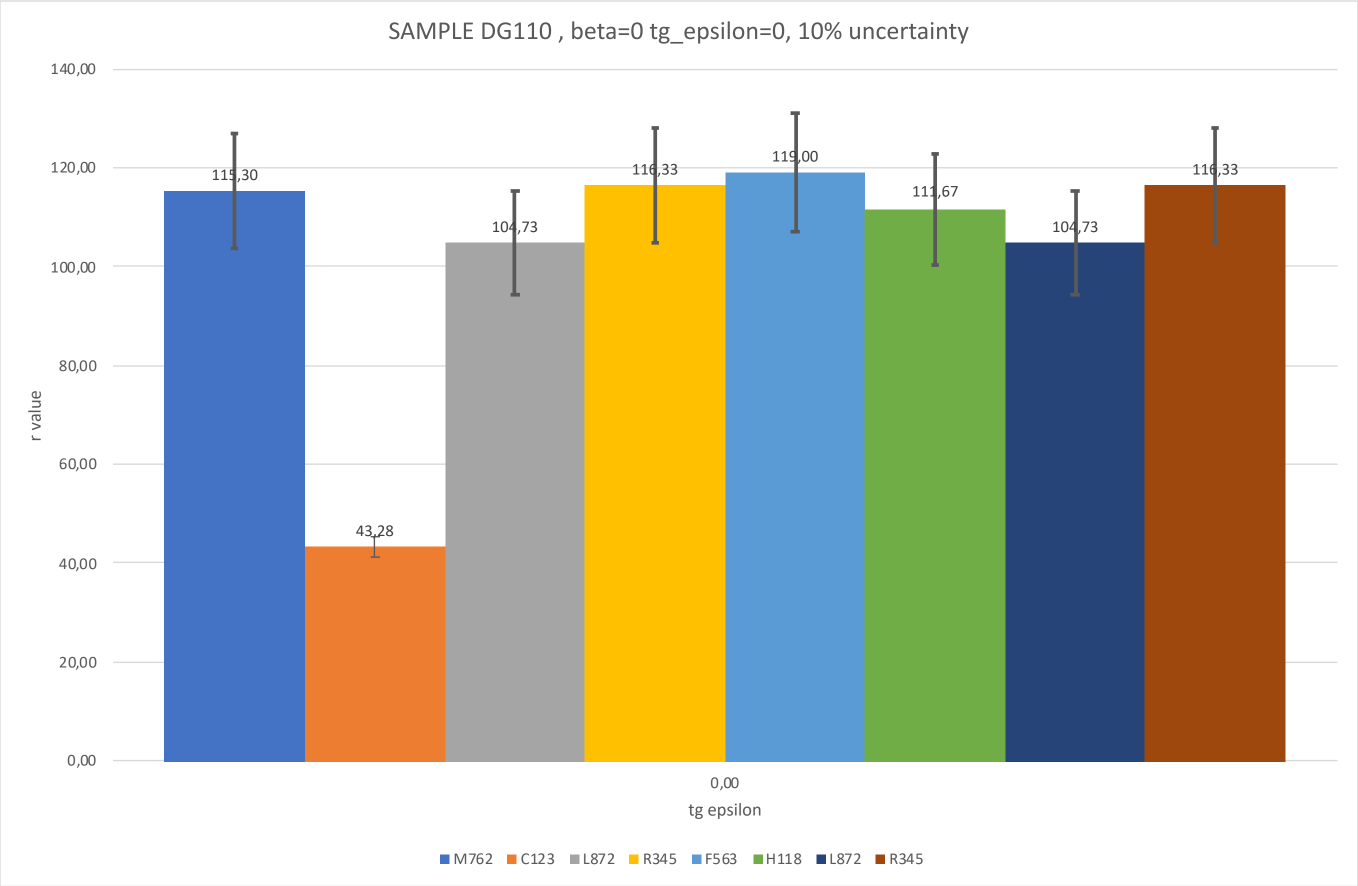


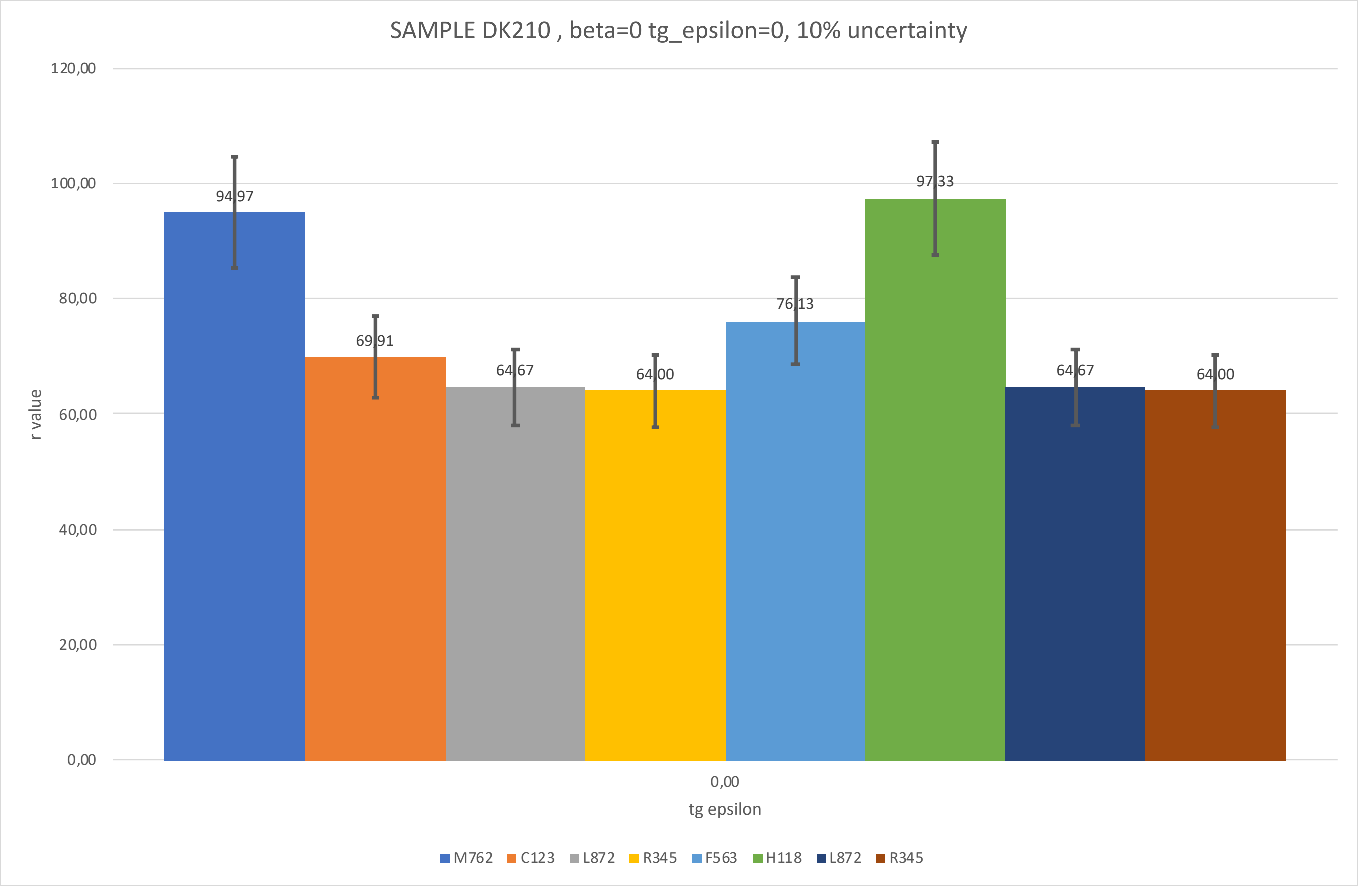
Figure 1. A schematic of the geometrical effects with left) apertures of the illumination A_S with coordinate system(x_S, y_S), of the detection A_D with coordinate system(x_D, y_D) and of the effective illuminated area A_E with coordinate system(x_E, y_E); right) the nominal angles (α_0, δ_0) of the detector and (β_0, ε_0) of the source.

Tan ε =0 β=0

DIFFUSE GREY HIGH HEIGHT DG110

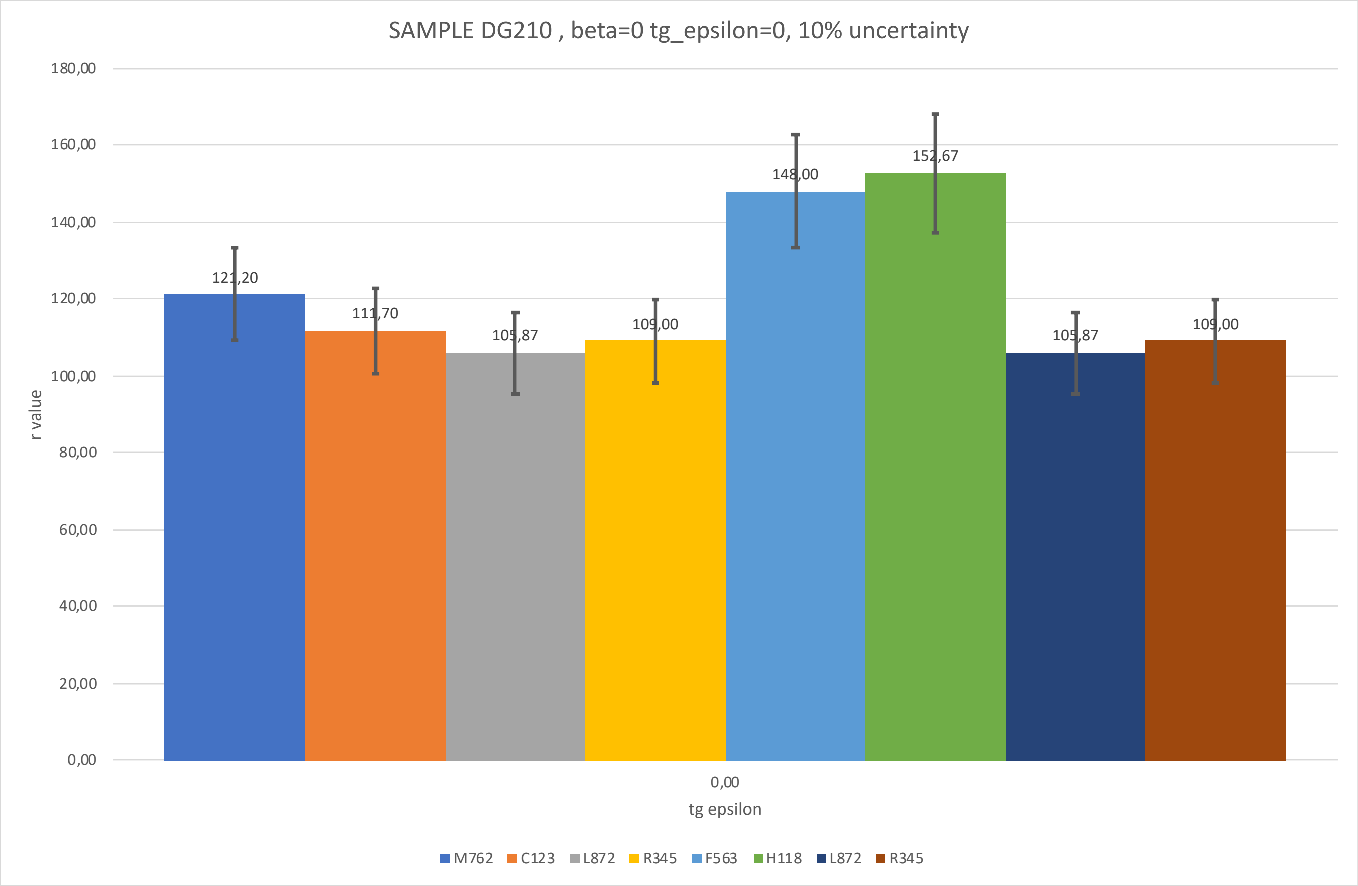


DIFFUSE BLACK LOW HEIGHT DK210



10%

DIFFUSE GREY LOW HEIGHT DG210



10%

Conclusions

- Even in SET A there are outliers, with discrepancies larger than 100%, greatest difficulties are with Glossy black sample
- Also in SET B there are outliers because of: single measurement value, systematic behaviour of laboratories
- Considering only the expected uncertainty of 10%, for condition with very low aperture effects, the compliance is quite good.
- For additional angular values the usage of LUMCORUN is necessary to evaluate (and correct) aperture effects

Samples DG210 DK210

- Diffuse Grey/ Black Low height

- The standard deviation of the measurements is not representative of the measurement uncertainty and is either an under-estimation or a mis-estimation.
  - Measurement devices showed good repeatability (all participant have low standard deviations)
  - The RM design ensured also high position and alignment repeatability.
  - The under/misestimation of the uncertainty involves problems in the approach to the definition of KCRV and consequently in degree of equivalence of the data
- As some measurements are outliers, the KCRV can be established relying only on few data. In few cases the results seem to belong to different populations: the choice of KCRV as arithmetic mean is weak it could be of interest to investigate the impact of considering just one laboratory as reference
- Some geometrical conditions shown good data agreement among the labs, while, in the larger part of geometries, discrepancies are relevant (in few cases more than 100%) to support the need of deeper investigations. Suggested field of investigations:
  - Impact of geometries, apertures and acceptance area and eventually calibration and calculation models
  - Need of systematic corrections for given instruments and/or given measurement directions